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# Crop levels and pruning timing affect must and wine quality of Cabernet Sauvignon wine grape

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## ABSTRACT

**Cabernet Sauvignon wine grape cultivar is well adapted in many of the tropical conditions of the globe and is also widely grown in Indian conditions. The experiment was conducted on Cabernet Sauvignon vines grafted on 110R rootstock and spaced at a distance of 2.438 × 1.219 m. These vines were pruned on 14, 21 and 28 Sep., 2012 as first pruning (P1), second pruning (P2) and third pruning (P3), respectively and crop levels of 20, 30 and 40 bunches per vine were maintained as L1, L2 and L3, respectively. Samples of must and young wines were collected and analyzed by using OenoFoss™ (a FTIR based wine analyzer). GC-MS with single quadrapole (source temperature of 230°C and quad temperature of 150°C) was used for estimation of aroma compounds. Analysis was carried out by DB-WAXetr column on full scan mode. The must and wine quality parameters were affected by both pruning time and crop levels. Wine from P1 was found with more ethanol as must of the same treatment contained more TSS. In case of crop level, L3 was recorded with maximum (10.80 per cent) ethanol followed by L2 and L1. The maximum titratable acidity in wines was recorded in L1 and minimum was in L3. The wines prepared from P2 with different crop levels were registered with higher colour intensity and maximum was in P2L2 (4.45). Delayed pruning combination with crop levels was noted in lower colour intensity and in P3L3 the value was only 2.20. Study on aroma compounds showed differences in conc. Wines from delayed pruning were found with better aromas.**

**Key words:** Wine grapes, fermentation, quality, aroma compounds.

## INTRODUCTION

Grape growing in tropical regions has been performed commercially since last 50 years. Among the tropical climatic conditions its cultivation is successful in the countries like Brazil, Thailand and Venezuela (Jogaiah *et al.*, 13). In India, commercial grape growing for table, resin and wine making has also been successful under tropical parts of Deccan plateau. Wine grape varieties including 'Cabernet Sauvignon' are well adapted in this region. Grape growing in tropical climate is different as compared to temperate climate. In tropics, vines enters in the dormancy and in temperate, due to winter chill, vines goes in to dormancy results in only one harvest in a year. Whereas, tropical climate offers optimum climatic conditions for vine growth that requires two pruning and single cropping this is adopted for both table as well as wine grape varieties. The vines are trained to mini Y system. The pruning is practiced during September-October and harvesting period is January to March in Maharashtra (Sharma *et al.*, 20).

India entered recently in wine grape production and facing quality issues as compared to international brands. The higher crop loads are in general associated with poor wine quality. Therefore, there is need to improve the wine grape quality through crop regulation and. There are also many other reason which are generally affect the wine grape quality like hot weather during harvest season, it may result in reduced wine quality due to poor quality of wine. Hence, standardization of agro-techniques for wine grape is prerequisite which should be in line with the prevailing climatic conditions. It has been known that the best wines obtained from those vineyards where vegetative growth and crop yield are in balance (Dry *et al.*, 7). Manipulation of crop load, either by post bloom cluster thinning or reduction in clusters after veraison, affect the characteristics in the final wine. An increase in crop load reduces must sugar, berry size, and pH, and increases total acidity, tartarate and malate (Boulton, 2). An indication of potential wine quality is reflected by lower pH, higher levels of colour, tannins, phenols and acidity. The aroma of the wine is known to be influenced by more than 1000 aroma compounds (Tao and Li, 21). Effects of crop level reduction are generally results in an increase in Brix, anthocyanins, total phenols, and color intensity (Jackson and Lombard, 12; Mazza *et al.*, 14; Reynolds *et al.*, 17). The diversity of aromatic compounds in wine is immense and ranges in concentration from several mg $l^{-1}$ to a few ng $l^{-1}$ (Zhang *et al.*, 23). Combinations and quantity of

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aroma compounds in wines affected by varieties, growing conditions, crop levels, training type and pruning time, yeast strain used for fermentation, fermentation conditions etc. Among the growing conditions, environmental conditions after veraison to harvest decide the content of sugars, acidity, anthocyanins, phenolics and tannin in grape berries. In tropical conditions, more sugar accumulates in berries and results in higher alcohol in wines. Advanced grape maturity and greater exposure to the sun favors the accumulation of varietal compound in the berry (Schneider *et al.*, 19). Lower canopy densities may produce an increase in glycosidically-bound compounds in the berry (Jackson and Lombard, 12; Zoecklein *et al.*, 24). High levels of alcohol can alter the sensorial quality of wines by increasing the perception of hotness and, to a lesser extent, by decreasing the perception of sweetness, acidity, and aroma (Escudero *et al.*, 8 and Gawel *et al.*, 9). Grapevine faces various abiotic stresses like high temperature, soil structure, salinity, irrigation water with high sodium content, low water availability etc. in this region. Standardization of pruning time and maintaining crop levels to obtain quality grapes for producing acceptable wines are main targets in tropical regions. Sometimes we have to consider profitability of grape growers as input cost is always higher in tropical regions. Systematic studies were initiated on varietal suitability under tropical conditions, water requirements; rootstock identification etc., but pruning time and suitable crop load to achieve quality wines was not targeted in previous studies. Prevailing temperature after veraison and impact of crop levels on grape quality is well established (Sharma *et al.*, 20). Present study was conducted to identify suitable pruning time and crop levels for obtaining quality wine of Cabernet Sauvignon under tropical growing conditions.

## MATERIALS AND METHODS

The vines of Cabernet Sauvignon grafted on 110R rootstock and spaced a distance of 2.438 × 1.219 m, were selected for the experiment. The vines were pruned on 14, 21 and 28 Sep 2012 as first pruning (P1), second pruning (P2) and third pruning (P3), respectively. The crop levels of 20, 30 and 40 bunches per vine were maintained as L1, L2 and L3, respectively. All the cultural practices like nutrient and irrigation management, plant protection measures, canopy management practices are followed as per the recommendations made for the region. The fruit samples were collected 150 days after pruning. The data on total acidity, TSS, pH was noted by using OenoFoss™ (FTIR based wine analyzer). The grapes were harvested when berries attained desired TSS. In each treatment, 10 vines were selected randomly and earmarked. Each treatment was replicated thrice. A group of about 100 berries, representing each and every vine was used to estimate berry parameters like pH, TSS and acidity. Three separate samples were collected from each treatment and analyzed.

A commercial wine yeast strain was used for fermentation of Cabernet Sauvignon grapes. The must was fermented in food grade plastic vessels which were kept at 20 ± 2°C. On 12$^{th}$ day when fermentation was completed, seeds and skin were separated from wines. During the fermentation process, the must were punched two times every day. The wines were stored at low temperature for racking and 80 ppm $SO_2$ was maintained by adding potassium metabisulphite. For analysis, the wine samples were collected from second racking. OenoFoss™ was used for obtaining data on different parameters. The collected data were statistically analyzed by using SAS program.

The final method for analyze volatiles compounds from grapes and wine involved extraction i.e. evaporation of all the major volatile compounds from the 2 mL fine crushed and homogenized sample taken in Head-Space vial of capacity 20 mL crimped with aluminum cap. The vial was kept in Head-Space sampler, before injection vial transferred to oven at 150°C for equilibration, equilibration time was 40 min. After complete equilibration volatile compounds from head space of vial transfer to loop, transfer line and back inlet having temperature 160°C, 170°C and 220°C, respectively. Sample was analyzed by GC-MS with single quadrupole had source temperature 230°C and quad temperature 150°C. Analysis was carried out by DB-WAXETR column on FULL SCAN mode (Banerjee *et al.*, 1).

## RESULTS AND DISCUSSION

The must quality is affected by both pruning time and crop load. The delayed pruning was resulted in less TSS, pH and total acidity. The maximum TSS (22.43°B) was recorded in P1 which was 22.13°B in P2 and 20.88°B in P3 (Table 1). Significantly higher TSS was found in P1 and P2 over P3. Among the pH values differences were non-significant. However, pH values were decreased by delayed pruning. Total titratable acidity was also recorded higher in early pruned vines. Volatile acidity was lesser and non-significant differences were observed. In case of crop levels, surprisingly low TSS was noted in L1 and L2 in comparison to L3 where crop level was higher. The pH was also increased with increasing crop level. By increasing crop level, reduction in total acidity content of must was noted. Maximum acidity

**Table 1.** Effect of pruning and crop load on must quality.

| Treatments | TSS (°B) | pH | Total acidity (g/l) | Volatile acidity (g/l) |
|---|---|---|---|---|
| Pruning | | | | |
| P1 | 22.43 | 3.85 | 6.13 | 0.06 |
| P2 | 22.13 | 3.73 | 6.03 | 0.07 |
| P3 | 20.88 | 3.71 | 5.63 | 0.06 |
| LSD at 5% | 0.326 | NS | 0.103 | NS |
| SEm± | 0.154 | 0.090 | 0.048 | 0.004 |
| Crop load | | | | |
| L1 | 21.46 | 3.74 | 6.06 | 0.07 |
| L2 | 21.72 | 3.76 | 5.90 | 0.06 |
| L3 | 22.26 | 3.80 | 5.83 | 0.06 |
| LSD at 5% | 0.326 | NS | 0.103 | NS |
| SEm ± | 0.154 | 0.090 | 0.048 | 0.004 |
| Interaction of P*L | | | | |
| P1L1 | 21.90 | 3.80 | 6.40 | 0.06 |
| P1L2 | 22.30 | 3.84 | 6.10 | 0.06 |
| P1L3 | 23.10 | 3.93 | 5.90 | 0.07 |
| P2L1 | 21.90 | 3.75 | 6.10 | 0.08 |
| P2L2 | 22.10 | 3.73 | 6.00 | 0.07 |
| P2L3 | 22.40 | 3.73 | 6.00 | 0.07 |
| P3L1 | 20.60 | 3.68 | 5.70 | 0.08 |
| P3L2 | 20.76 | 3.72 | 5.60 | 0.06 |
| P3L3 | 21.30 | 3.74 | 5.60 | 0.06 |
| LSD at 5% | 0.565 | NS | 0.178 | 0.018 |
| SEm ± | 0.266 | 0.156 | 0.084 | 0.008 |

was recorded in L1 and minimum was in L3. Very low values of volatile acidity were noted with non-significant differences. Interaction data of pruning time and crop levels showed significant differences except volatile acidity. The maximum TSS (23.10°B) was noted P1L3; while, minimum (20.60°B) was in P3L1. Non-significant differences were noted in pH values and minimum pH i.e. 3.68 was observed in P3L1. The combination of P1L1 was registered with maximum total acidity (16.40 g/L) and minimum acidity was found in P3L1. Volatile acidity was within the range of 0.06 to 0.08 and maximum was in P2L1 and P3L1.

The quality of grapes reflects in wine quality. Data on wine quality parameters are given in Table 2. Delayed pruning was noted in reduced acid content and increased pH. Total acidity was maximum (5.16 g/L) in wine obtained from P2 followed by P1 and P3. More ethanol (11.03) was noted in P1 followed by P3 (10.83) while it was surprisingly lowest in P2 (8.83). Minimum malic acid (2.54 g/L) was found in P1 and maximum (3.20 g/L) was recorded in P2 followed by P3. Same pattern was followed in case of volatile acidity which was ranged 0.50 to 0.62 g/L. Wine obtained from P2 having maximum colour intensity (4.26) followed by P1 (3.65). In case of crop levels, maximum total acidity (4.90 g/L) was observed in L3 followed by L2 and L1. While, minimum pH (3.84) was noted in L2. Ethanol content was maximum (10.80 per cent) in L3 followed by L2 and L1. Malic content in wines was ranged from 2.73 to 2.90 g/L and maximum was noted in L1 followed by L2 and L3. Volatile acidity was found within the range of 0.56 to 0.65 g/L and minimum was note in L1. The maximum colour intensity (3.77) was observed in L2 followed by L1 and L3. As per data of interaction, total acidity was varied from 3.90 to 5.30 g/L and pH was noted in the range of 3.73 to 4.10. The combinations of P2 with all crop levels were noted with surpassingly low ethanol per cent in wines. However, the range was varied 7.00 to 11.70 and maximum was recorded in combination of P1L3. Comparatively more acidity was noted in wines prepared from P2 crop levels and maximum malic acid content (3.60 g/L) was noted in P2L1 while in wine P1L3 it was only 2.30 g/L. Volatile acidity was ranged within 0.45 to 0.73 g/L and minimum was observed in P3 L1 and P3L2 while maximum was in P2L3. The wines prepared from P2 with different crop levels were registered with higher colour intensity and maximum was in P2L2 (4.45). Delayed pruning combination with crop levels was noted in lower colour intensity and in P3L3 the value was only 2.20.

It is found that high-yielding vines produce lower-quality wines. The relationship between the crop level and the wine quality has been widely investigated and reviewed from various wine regions (Sharma, *et al*., 20). Pruning and harvesting practices in vineyards are decided considering the grape quality requirements of wineries with desirable TSS. Beside pruning time, crop level has its own impact on wine quality. This trend concurs with the previous work of Guidoni *et al*. (11) who concluded that a 50% cluster removal at pea size increased the TSS by 7% at harvest. Similarly Gu, *et al*. (10) also reported that crop thinning increases the rate of sugar accumulation and thereby can advance the time of harvest.

In present study higher TSS was noted in early pruning and reduction in acidity of must was recorded with delayed pruning. As a general trend, the pH increased along with the sugar concentration as grapes matured and total acids declined. Increased crop level was resulted in declining trend in acidity in must. Sharma *et al*. (20) also recorded results in same manner. The results obtained from wines

**Table 2.** Effect of pruning and crop load on wine quality of Cabernet Sauvignon.

| Treatments | Gl /Fr (g/l) | Total acidity (g/l) | pH | Ethanol % (v/v) | Malic Acid (g/l) | Volatile acidity (g/l) | Colour Intensity |
|---|---|---|---|---|---|---|---|
| Pruning | | | | | | | |
| P1 | 1.39 | 4.80 | 3.73 | 11.03 | 2.54 | 0.62 | 3.65 |
| P2 | 1.20 | 5.16 | 3.85 | 8.83 | 3.20 | 0.66 | 4.26 |
| P3 | 0.43 | 4.23 | 4.04 | 10.83 | 2.63 | 0.50 | 2.70 |
| LSD at 5% | 0.083 | 0.101 | 0.140 | 1.775 | 0.172 | 0.024 | 0.210 |
| SEM± | 0.039 | 0.047 | 0.066 | 0.837 | 0.081 | 0.011 | 0.099 |
| Crop load | | | | | | | |
| L1 | 0.83 | 4.63 | 3.90 | 9.33 | 2.90 | 0.56 | 3.57 |
| L2 | 1.36 | 4.66 | 3.84 | 10.56 | 2.74 | 0.57 | 3.77 |
| L3 | 0.83 | 4.90 | 3.88 | 10.80 | 2.73 | 0.65 | 3.27 |
| LSD at 5% | 0.083 | 0.101 | NS | NS | NS | 0.024 | 0.210 |
| SEM ± | 0.039 | 0.047 | 0.066 | 0.837 | 0.081 | 0.011 | 0.099 |
| Interaction of P*L | | | | | | | |
| P1L1 | 1.49 | 4.70 | 3.74 | 10.40 | 2.60 | 0.63 | 3.63 |
| P1L2 | 1.50 | 4.90 | 3.73 | 11.00 | 2.73 | 0.64 | 3.96 |
| P1L3 | 1.20 | 4.80 | 3.74 | 11.70 | 2.30 | 0.61 | 3.35 |
| P2L1 | 0.90 | 5.30 | 3.88 | 7.00 | 3.60 | 0.61 | 4.08 |
| P2L2 | 1.40 | 5.10 | 3.84 | 9.80 | 3.10 | 0.64 | 4.45 |
| P2L3 | 1.30 | 5.10 | 3.85 | 9.70 | 2.90 | 0.73 | 4.27 |
| P3L1 | 0.10 | 3.90 | 4.10 | 10.60 | 2.50 | 0.45 | 3.00 |
| P3L2 | 1.20 | 4.00 | 3.96 | 10.90 | 2.40 | 0.45 | 2.91 |
| P3L3 | 0.00 | 4.80 | 4.06 | 11.00 | 3.00 | 0.62 | 2.20 |
| LSD at 5% | 0.144 | 0.175 | 0.243 | 3.075 | 0.299 | 0.042 | 0.363 |
| SEM ± | 0.068 | 0.082 | 0.114 | 1.450 | 0.141 | 0.020 | 0.171 |

were almost similar to must quality. More ethanol was observed in P1 as must of made from the same treatment contained more TSS than P2 and P3. Acidity was surprisingly higher in P2 wine. But ethanol content was minimum in P3. Wine from P2 contained maximum colour intensity followed by P1. It has been reported by earlier workers that the development of color in grapes is highly determined by prevailing light and temperature conditions (Jogaiah *et al*., 13). In both P1 and P3 where the pruning was done early or late, the berry ripening must have coincided with low temperature or high temperature which either reduced the synthesis of anthocyanins or degraded the accumulated anthocyanins. The temperature and light intensity mush have been optimum in the treatment P2 which has recorded maximum color intensity. Berries from delayed pruning face higher temperature at the time of maturity under tropical conditions it results in poor colour development in berry skin. Late pruning results in negative effect of high temperature on colour density, tannin and total anthocyanin content in wines (Sadras, 18). Mori *et al*. (15) reported that high night time temperatures tend to decrease anthocyanin accumulation and tropical Indian conditions, if pruning is delayed results in higher temperature at the time of ripening and results in poor colour development. More crop loads results in reduced wine quality (Bravdo *et al*, 4). Di Profio *et al*. (5), found that cluster thinning treatments on Cabernet franc, Cabernet Sauvignon and Merlot had the highest wine anthocyanin and phenol concentrations and the highest color intensities with respect to control, with an increase in pH and a reduction in TA, the last being directly correlated with the results of TA on berry and must as well as color and total anthocyanins (DiProfio *et al*., 6).

The GC-MS is widely used for identification and quantification of aroma compounds in wines. In present study, vine plots were differentiated by pruning time and results were demonstrated by analysing the volatile compounds effect due to the different pruning dates. In present study, 19 aroma compounds were identified and quantified (Table 3). These were mainly organic acids (2), higher alcohols (9), aldehydes (4), esters (2), ketone (1) and glycerol. Acetic acid was noted with higher concentration than active valeric acid. However, downward trend was noticed in acetic acid concentration. Among the alcohols Phenethyl alcohol was dominant with concentration of 990 µg/L followed by 2, 3 Butanediol in P1. In P2 also Phenethyl alcohol showed dominance with concentration of 1318 µg/L and followed by Iso-amyl alcohol (1235 µg/L). In P3, maximum concentrations recorded by Iso-amyl alcohol (1655 µg/L) and followed by Phenethyl alcohol. It means delayed pruning was resulted in dominance of Iso-amyl alcohol. Butanol was absent in P1 but appeared in P2 and similarly Acetol was present in P1 which was found absent in P2 and P3. Delayed pruning was resulted in increased conc. of iso amyl alcohol, butanol and 2,3 Butanediol. 2,3 Butanediol displays the fruity, sweet and buttery note in wine aroma while butanol and iso-amyl alcohols are related to sweet, solvent and nail polish notes in wines. Acetaldehyde emerged major compound in P2 (219 µg/L) and P3 (119 µg/L). Acetaldehyde is known for pleasant aroma at lower conc. Conc. of acetaldehyde in wines was increased in delayed pruning. However, wines of present study have lower concentrations. So wines of delayed pruning have good aromas. Maximum content of Furfural (34 µg/L) was recorded in P1. Ethyl acetate was dominant ester with the maximum concentration of 99 µg/L in P2 followed by P3. Presence of ethyl acetate in wines shows fruity and pineapple aromas. Increased concentration of ethyl acetate give a sign of better aromas in wines which note in wines obtained from delayed pruning.

Quantity of acetic acid was more than active valeric acid in studied crop levels and by increasing crop levels, concentration of these acids were also increased. However, concentration of acetic acid was much higher. Among the alcohols, Phenethyl alcohol was dominant with 2016, 3045 and 4607 µg/L in L1, L2 and L3, respectively and followed by 2, 3 Butanediol. Presence of acetol was masked in L1 while it appeared in L2 and L3. Among the compounds of aldehyde group, concentration of acetaldehyde was maximum in lower crop level while in L2 and L3

**Table 3.** Effect of Pruning date on volatile compounds of Wine.

| S. No. | Compound | Group | P1 | | P2 | | P3 | |
|---|---|---|---|---|---|---|---|---|
| | | | Peak Area | Conc. (µg/L) | Peak Area | Conc. (µg/L) | Peak Area | Conc. (µg/L) |
| 1 | Acetic acid | Acid | 9050487 | 711 | 5860936 | 496 | 5032927 | 336 |
| 2 | Active valeric acid | Acid | 135740 | 11 | 200906 | 17 | 182821 | 12 |
| 3 | 3-Octanol (IS) | Alcohol | 1273703 | 100 | 1182651 | 100 | 1496081 | 100 |
| 4 | Iso-Butyl alcohol | Alcohol | 92945 | 7 | 907435 | 77 | 1585600 | 106 |
| 5 | 1-Butanol | Alcohol | - | 0 | 75121 | 6 | 95610 | 6 |
| 6 | Iso-amyl alcohol | Alcohol | 1960321 | 154 | 14599964 | 1235 | 24753250 | 1655 |
| 7 | Acetol | Alcohol | 55888 | 4 | - | 0 | - | 0 |
| 8 | 2,3 Butanediol | Alcohol | 9704075 | 762 | 8502267 | 719 | 4128311 | 276 |
| 9 | 1,2 Propanediol | Alcohol | 191418 | 15 | 287689 | 24 | 156593 | 10 |
| 10 | 1-Propanol, 3 Methylthio | Alcohol | 53654 | 4 | 73166 | 6 | 59711 | 4 |
| 11 | Phenethyl alcohol | Alcohol | 12609007 | 990 | 15591202 | 1318 | 14725573 | 984 |
| 12 | Acetaldehyde | Aldehyde | 129447 | 10 | 2585717 | 219 | 1786665 | 119 |
| 13 | Iso-Butyraldehyde | Aldehyde | 297955 | 23 | 251618 | 21 | 188250 | 13 |
| 14 | Furfural | Aldehyde | 436446 | 34 | 155549 | 13 | 281395 | 19 |
| 15 | 2-Furaldehyde, 5 hydroxy methyl | Aldehyde | 167516 | 13 | 534878 | 45 | 83271 | 6 |
| 16 | Ethyl acetate | Ester | 78810 | 6 | 1165856 | 99 | 1012706 | 68 |
| 17 | Ethyl lactate | Ester | 87003 | 7 | 69825 | 6 | 182934 | 12 |
| 18 | Butyl Lactone | Ketone | 277933 | 22 | 88894 | 8 | 60891 | 4 |

and furfural was found dominant with 145 and 149 µg/L (Table 4). 2-Methyl Butanal showed presence in L1 only. In L1 and L2 ethyl acetate was noticed with more conc. while in L3 ethyl lactate was more than ethyl acetate. So, more conc. of ethyl acetate shows fruity nature of aromas in L1 and L2 wines.

Volatile acidity contributes to the basic aroma of wine, but in excess can be regarded as undesirable or offensive. Fusel alcohols have a strong pungent smell and taste. Although they exhibit a harsh flavours, unpleasant aroma at the concentrations generally found in wine, below 300 m/L they usually contribute to the desirable complexity of wine. High levels of alcohol can alter the sensorial quality of wines by increasing the perception of hotness and, to a lesser extent, by decreasing the perception of sweetness, acidity, and aroma (Escudero *et al*., 8 and Gawel *et al*., 9). Short chain, volatile aldehydes are important to the flavour and aroma of wine. Characteristic contributing flavours range from “apple-like” to “citrus-like” to “nutty” depending on the chemical structure. The fresh, fruity aroma of young wines derives in large part from the presence of the mixture of esters produced during fermentation. Esters with the exception of ethyl acetate, contribute fruit and flower notes to wine aroma. Glycerol is usually found in wines at concentrations in the range of 5 to 9 g/liter and contributes positively to the quality of wine by providing body and sweetness (Noble and Bursick, 16).No relationship to wine quality was observed when Boulton (2) managed three crop levels by cluster thinning right after fruit set: unthinned control (60 to 80 clusters/vine); medium crop level (40 cluster/vine retained); low crop level (20 clusters/ vine retained).But in present study, differences in concentrations of various compounds are observed. Composition of aroma compounds in given wine decides flavour of wine. Presence of Acetol was disappeared in delayed pruning while butanol was appeared in wines prepared from P2 and P3. Bravdo *et al*. (3) described that quality tended to be slightly better in wines made with Cabernet Sauvignon of the unthinned treatment than in wines from reduced crop imposed after bloom. Bravdo *et al*. (4) found that the volatile acids were high in unthinned wines in two years. Wood (22) concluded that the lowest crop load does not always result in premium wine quality. Crop thinning had a detrimental effect on

**Table 4.** Effect of crop load on volatile compounds in wines.

| S. No. | Compound | Group | L1 | | L2 | | L3 | |
|---|---|---|---|---|---|---|---|---|
| | | | Peak Area | Conc. (µg/L) | Peak Area | Conc. (µg/L) | Peak Area | Conc. (µg/L) |
| 1 | Acetic acid | Acid | 7825497 | 1312 | 8861191 | 2334 | 9050487 | 7825497 |
| 2 | Active valeric acid | Acid | 177649 | 30 | 148430 | 39 | 135740 | 50 |
| 3 | 3-Octanol (IS) | alcohol | 596324 | 100 | 379687 | 100 | 273703 | 100 |
| 4 | Iso-Butyl alcohol | alcohol | 302959 | 51 | 160486 | 42 | 92945 | 34 |
| 5 | Iso-amyl alcohol | alcohol | 5902031 | 990 | 3432786 | 904 | 1960321 | 716 |
| 6 | Acetol | alcohol | BDL | 0 | 86379 | 23 | 55888 | 20 |
| 7 | 2,3 Butanediol | alcohol | 7934090 | 1330 | 9694792 | 2553 | 9704075 | 3545 |
| 8 | 1,2 Propanediol | alcohol | 145788 | 24 | 201231 | 53 | 191418 | 70 |
| 9 | 1-Propanol, 3 Methylthio | alcohol | 34117 | 6 | 58159 | 15 | 53654 | 20 |
| 10 | Phenethyl alcohol | alcohol | 12020696 | 2016 | 11561899 | 3045 | 12609007 | 4607 |
| 11 | Acetaldehyde | Aldehyde | 475960 | 80 | 154620 | 41 | 129447 | 47 |
| 12 | Iso-Butyraldehyde | Aldehyde | 426986 | 72 | 309099 | 81 | 297955 | 109 |
| 13 | 2-Methyl Butanal | Aldehyde | 53806 | 9 | BDL | 0 | BDL | 0 |
| 14 | Furfural | Aldehyde | 260928 | 44 | 550388 | 145 | 436446 | 159 |
| 15 | 2-Furaldehyde, 5 hydroxy methyl | Aldehyde | 28032 | 5 | 32722 | 9 | 167516 | 61 |
| 16 | Ethyl acetate | Ester | 235226 | 39 | 143206 | 38 | 78810 | 29 |
| 17 | Ethyl lactate | Ester | 118405 | 20 | 116528 | 31 | 87003 | 32 |
| 18 | Butyl Lactone | Ketone | 125473 | 21 | 194433 | 51 | 277933 | 102 |

BDL: Below Detectable Limit

wine quality by disturbing the natural balance of the vine, increasing vegetative growth and negatively affecting the light environment within the fruiting zone. The must quality is affected by both pruning time and crop levels in present study. Presence and concentrations of aroma compounds has own role deciding acceptance level of wines. In present study aroma compounds and their concentrations in wines were affected by pruning dates and crop levels. However, further studies are needed based on accumulated degree days, relation of environmental conditions after veraison with sugar types, their ratios, different type acids and their levels in berries. Such type studies will helpful in defining aromas of wines obtained from tropical conditions.

## REFERENCES


1. Banerjee, K., Kambale, N., Uttare, S. and Kandaswamy, C. 2015. Volatile profiling in wine using gas chromatography mass spectrometry with thermal desorption. P*ublication Part Number: 5991-5680EN*. http://www.agilent.com/cs/library/applications/5991-5680EN.pdf

2. Boulton, R. 1980. The relationship between total acidity, titratable acidity and pH in grape tissue. *Vitis*, **19**: 113-20.

3. Bravdo, B., Hepner, Y., Loinger, C., Cohen, S. and Tabacman, H. 1985. Effect of crop level and crop load on growth, yield, must and wine composition, and quality of Cabernet sauvignon. *Am. J. Enol. Vitic*. **36**: 125-31.

4. Bravdo, B., Hepner, Y., Loinger, C., Cohen, S. and Tabacman, H. 1984. Effect of crop level on growth, yield and wine quality of a high yielding Carignane vineyard. *American J. Enol. Vitic*. **35**: 247-52.

5. Di Profio, F., Reynolds, A.G. and Kasimos, A. 2011. Canopy management and enzyme impacts on Merlot, Cabernet franc, and Cabernet Sauvignon. II. Wine composition and quality. *American J. Enol. Vitic*. **62**: 152-68.

6. Di Profio, F., Reynolds, A.G. and Kasimos, A. 2011. Canopy management and enzyme impacts on Merlot, Cabernet Franc, and Cabernet Sauvignon. I. Yield and berry composition. *American J. Enol. Vitic*. **62**: 139-51.

7. Dry, P.R., Iland, P.G. and Ristic, R. 2004. What is Vine Balance? Proceedings from the 12th Australian *Wine Industry Technical Conference.* Melbourne, Victoria 68-74 pp.

8. Escudero, A., Campo, E., Fariña, L., Cacho, J. and Ferreira, V. 2007. Analytical characterization of the aroma of five premium red wines. Insights into the role of odor families and the concept of fruitiness of wines. *J. Agric. Food Chem*. **55**: 4501-10. DOI: 10.1021/jf0636418

9. Gawel, R, Francis, L. and Waters, E.J. 2007. Statistical correlations between the in-mouth textural characteristics and the chemical composition of Shiraz wines. *J. Agric. Food Chem*. **55**: 2683-87. DOI:10.1021/jf0633950

10. Gu, S., Guan, X. and Wample, R.L. 2006. Impact of hang time on yield, fruit composition and vine health under different pruning regimes and crop levels in Syrah grapes. *ASVE 57*, *Annual Meeting*, *Technical Abstracts*, 10 p. http://www.asev.org/sites/main/files/file-attachments/2006abstractbook_0.pdf

11. Guidoni, S., Allan, P. and Schubert, A. 2002. Effect of cluster thinning on skin anthocyanins composition in *Vitis vinifera* cv. Nebbiolo. *American J. Enol. Vitic*. **53**: 409-30.

12. Jackson, D.I. and Lombard, P.B. 1993. Environmental and management practices affecting grape composition and wine quality-a review. *American J. Enol. Vitic*. **44**: 409-30.

13. Jogaiah, S., Oulkar, D.P., Vijapure, A.N., Maske, S.R., Sharma, A.K. and Somkuwar, R.G. 2013. Influences of canopy management practices on fruit composition of wine grape cultivars grown in semi-arid tropical region of India. *African J. Agrl. Res*. **8**: 3462-72.

14. Mazza, G., Fukumoto, L., Delaquis, P., Girard, B. and Ewert, B. 1999. Anthocyanins, phenolics, and color of Cabernet franc, Merlot, and Pinot noir wines from British Columbia. *J. Agr. Food Chem*. **47**: 4009-17. DOI: 10.1021/jf990449f

15. Mori, K., Sugaya, S. and Gemma, H. 2005. Decreased anthocyanin biosynthesis in grape berries grown under elevated night temperature condition. *Scientia Hort*. **105**: 319-33.

16. Noble, A.C. and Bursick, G.F. 1984. The contribution of glycerol to perceived viscosity and sweetness in white wine. *American J. Enol. Vitic*. **35**: 110-12.

17. Reynolds, A.G., Price, S.F., Wardle, D.A. and Watson, B.T. 1994. Fruit environment and crop

level effects on Pinot Noir. I. vine performance and fruit composition in British Columbia. *American J. Enol. Vitic*. **45**: 452-59.

18. Sadras, V. 2016. Decompressing harvest and preserving wine identity. *Final report to Australian Grape & Wine Authority. Project Number*: SAR1304. https://www.wineaustralia.com/getmedia/eddc9bf0-fb83-47b4-bdf3-0c74170241be/SAR-1304-Final-Report-Delayed-pruning

19. Schneider, R., Razungles, A., Charrier, F. and Baumes, R. 2002. Effet du site, de la maturitéet de l'éclairement des grapes sur la composition aromatique des baies de Vitisvinifera L. cv. Melon B. dans le vignoble du Muscadet. *Bulletin de l'O.I.V*, **855–856**: 270-82.

20. Sharma A.K., Somkuwar, R.G., Banerjee, K. and Jogaiah, S. 2016. Effect of crop levels and pruning timing on bunch and berry parameters of Cabernet Sauvignon grapes. *J. Agri. Search*, **3**: 165-69.

21. Tao, Y.S. and Li, H. 2009. Active volatiles of cabernet sauvignon wine from Changli county. *Natural Science*, **1**: 176-82.

22. Wood, C.McD. 2011. The effect of crop load and extended ripening on wine quality and vine balance in *Vitis vinifera* cv. Cabernet Sauvignon. Ph.D. thesis, The University of Adelaide. https://digital.library.adelaide.edu.au/dspace/bitstream/2440/65873/9/01front.pdf

23. Zhang, M., Pan, Q., Yan, G. and Duan, C. 2011. Using headspace solid phase micro-extraction for analysis of aromatic compounds during alcoholic fermentation of red wine. *Food Chem*. **25**: 743-49. DOI:10.1016/j.foodchem.2010.09.008

24. Zoecklein, B.W., Wolf, T.K., Marcy, J.E. and Jasinski, Y. 1998. Effect of fruit zone leaf thinning on total glycosides and selected aglycone concentrations of Riesling (*Vitis vinifera* L.) grapes. *American J. Enol. Vitic*. **49**: 35-43.

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